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CLINICAL RESEARCH

Mechanical circulatory assistance in myocardial infarction with refractory cardiogenic shock: clinical experience in 10 patients at a teaching hospital in Rouen

Assistance circulatoire et infarctus du myocarde avec choc cardiogénique réfractaire ; expérience du CHU de Rouen : à propos de 10 cas

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KEYWORDS

Cardiogenic shock;
Myocardial infarction;
Circulatory
assistance;
Extracorporeal
Membrane
Oxygenation system
(ECMO).

Summary

Background. — In patients with acute myocardial infarction (MI), cardiogenic shock (CS) remains associated with a high mortality (close to 50%) despite optimal therapeutic strategy. For those patients who are unlikely to survive, mechanical circulatory support (MCS) might be an additional life saving strategy.

Objective. — To evaluate the efficacy of circulatory assistance in myocardial infarction complicated by cardiogenic shock.

Methods. — We retrospectively studied the characteristics and clinical outcome of 10 patients hospitalized with acute MI and CS who required MCS. Mean age was 52±8 years; location of MI was anterior in 80% of cases. Immediate coronary angiography was performed in all cases 5.8±7.0 hours from the onset of symptoms. Intra-aortic balloon pumping was used in 70% of patients and 30% received thrombolysis. Angioplasty with stent implantation was performed in 8 patients.

Results. — In all patients MCS was placed within a mean of 57±92 hours after admission for hemodynamic instability (systolic aortic pressure: 85±13 mmHg; mean: 64±10 mmHg). Extracorporeal membrane oxygenation (ECMO) was implanted in 8 patients followed by Thoratec™ in one. The other 2 patients received a Thoratec™ and a Heartmate II™ system respectively. Survival rate was 40% (4 patients): 3 patients underwent heart transplantation at a mean of 93±97 days and one patient is alive with definitive implantable Heartmate™. The other six patients died in hospital.

Conclusion. — Mechanical circulatory support appeared life saving in 4 out of 10 patients with acute MI and cardiogenic shock refractory to optimal treatment. In this situation, circulatory assistance deserves discussion and the choice of optimal device should be further evaluated.

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MOTS CLÉS

Choc cardiogénique;
Infarctus
du myocarde;
Assistance
circulatoire;
ECMO.

Résumé

Justification. — Malgré une stratégie thérapeutique optimale, la mortalité des patients en choc cardiogénique (CC) à la phase aiguë de l'infarctus du myocarde (IDM) reste élevée proche de 50%. Pour ces patients au pronostic vital engagé, l'assistance circulatoire mécanique (ACM) est une alternative thérapeutique.

Objectifs. — Evaluer l'efficacité d'une assistance circulatoire dans le choc cardiogénique compliquant un infarctus du myocarde.

Méthodes. — Nous avons étudié rétrospectivement les caractéristiques cliniques et l'évolution de 10 patients hospitalisés pour IDM compliqué de CC, ayant nécessité une ACM. L'âge moyen était de 52 ± 8 ans, l'IDM était antérieur dans 8 cas. Une coronarographie a été réalisée en urgence dans tous les cas, $5,8 \pm 7$ heures après le début des symptômes. Un ballon de contrepulsion intra-aortique a été utilisé dans 70% des cas et 30% des patients ont été traités par thrombolyse. Une angioplastie a été réalisée chez 8 patients.

Résultats. — Une ACM a été mise en place 57 ± 92 heures après l'admission pour instabilité hémodynamique (pression aortique systolique : 85 ± 13 mmHg ; moyenne : 64 ± 10 mmHg). Une ECMO a été implantée chez 8 patients, suivie d'un Thoratec dans un cas. Les 2 autres patients ont reçu un Thoratec™ et un Heartmate II™. Le taux de survie était de 40% : 3 patients ont été transplantés dans un délai de 93 ± 97 jours et un patient a été assisté par le dispositif Heartmate II™. Les autres patients sont décédés pendant la période hospitalière.

Conclusion. — L'ACM a permis la survie de 4 patients sur 10 à la phase aiguë d'un IDM compliqué de CC réfractaire au traitement conventionnel. Dans cette situation, l'assistance circulatoire mérite d'être discutée.

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Introduction

While the widespread use of initial reperfusion intervention has lead to a significant reduction in overall mortality from myocardial infarction (MI), cardiogenic shock (CS) remains a life-threatening complication (mortality rate of approximately 50%) and is still the primary cause of death in patients hospitalized for MI (1). In fact, over the past 25 years the incidence of cardiogenic shock has shown no sign of reduction, remaining a major complication in 8 to 10% of all treated MI (2). Inotropes, vasopressors and intra-aortic balloon pump (IABP) provide an increase in cardiac output of approximately 0.5l/min. When a larger increase is necessary, mechanical circulatory support (MCS) may offer an interesting alternative therapeutic approach. It should enable sufficient hemodynamic stability to be maintained while diminishing the workload on the heart, hence aiding its recovery. The use of emergency mechanical support has been frequently discussed in MI complicated by cardiogenic shock (3). Its use was first described in 1986 (4). Since then numerous reports of its usage have been published (5). In this study, we report our results from employing mechanical circulatory support in MI complicated by refractory cardiogenic shock.

Methods

This is a retrospective, single-centre, descriptive study of 10 consecutive patients hospitalized between January 2000 and December 2006 (the first patient was admitted in January 2000 and the other 9 after January 2002). The patients were admitted to the Charles Nicolle Hospital in Rouen with MI complicated by cardiogenic shock, necessita-

ting the implantation of a device providing mechanical circulatory assistance.

Myocardial infarction was defined as an acute coronary syndrome associated with chest pain, ST-segment elevation with Q-wave or a left bundle branch block on ECG. The diagnosis of cardiogenic shock was made if there was prolonged hypotension (systolic arterial pressure < 90mmHg for at least 30 minutes or the need to use inotropic or vasopressive pharmacological agents to maintain systolic arterial pressure ≥ 90 mmHg), the presence of clinical signs of peripheral hypoperfusion and a heart rate of ≥ 60 beats per minute. Right heart cardiac catheterization was not carried out systematically. Immediate angiographic success was defined as stent placement with < 30% residual stenosis and a normal arterial flow (TIMI [Thrombosis In Myocardial Infarction] flow grade 3).

The mechanical circulatory assistance device used most frequently in our study was the Extracorporeal Membrane Oxygenation (ECMO) system (Medos® Berlin, and Jostra® Hirrlingen, Germany). This extracorporeal circulation system can pump the same volume as the heart and therefore sustain the patient stably. The ECMO is implanted percutaneously or by surgical insertion into the femoral vessels. The cannula implanted into the femoral vein is guided upwards to the right atrium to drain venous blood. A centrifugal pump pushes the blood across the oxygenator and it is reinjected into the aorta via a cannula implanted in a peripheral artery. The Thoratec™ PVAD (Paracorporeal Ventricular Assist Device) system was used in our first patient and an IVAD (Intracorporeal Ventricular Assist Device) system in another case. This device offering biventricular mechanical circulatory assistance is driven by an external pneumatic energy source connected to a either fixed or mobile console.

The artificial ventricles were so positioned as to bypass the patient's heart, which was left in place. The HeartMate II™

system is a left ventricular assist device where the power-pack is connected midway between the point of the left ventricle and the aorta. The inflow cannula is connected to the apex of the left ventricle and the outflow cannula is sutured terminolaterally to the ascending aorta. Electrical energy is provided via a console or batteries, which permit several hours of autonomy. Circulatory assistance devices such as the Thoratec™ and HeartMate II™ (Thoratec Corporation, Pleasanton, CA) require surgical implantation and sternotomy. In our centre the procedure is always carried out with the patient on extracorporeal circulatory bypass.

The follow-up of patients was made possible by the use of the Charles Nicolle Hospital's computerized medical record management system (CDP2). All values were expressed as mean \pm standard deviation.

Results

Between 2002 and 2006, 679 patients with acute myocardial infarction (AMI) underwent coronary angiography in our center. Amongst these, 39 (4.4%) presented with cardiogenic shock. In 10 of these patients it was necessary to implant a mechanical circulatory assist device. The mean age of these patients was 52 ± 8 years (41 to 64 years). The female to male ratio was 1 to 9 men. The predominant risk factor was smoking (70%) followed by hypercholesterolemia (40%) and hypertension (30%). Additionally, 20% of patients had a family history of MI.

The infarction in 8 patients was located in the anterior wall and in the other two in the inferior wall. The initial medical treatment of the MI was provided by the ambulance service (SAMU) in 80% of cases within an average delay of 3.9 ± 8 h from symptom onset. Four of the patients were resuscitated following cardiac arrest and 5 others were intubated and ventilated. Thrombolysis was performed pre-admission in 30% of patients within 57 ± 17 min. Seven patients were admitted directly to the catheterization laboratory, while two patients needed immediate medical resuscitation and the last patient was admitted into the intensive care unit. On admission, mean systolic aortic pressure was 85 ± 13 mmHg; mean arterial pressure 64 ± 10 mmHg. Eight patients were in cardiogenic shock on admission and the other two developed shock within 12 hours. All patients received pharmacological support with inotropes and/or vasopressors. No sign of mechanical complication was evident on ultrasound examination. The mean ejection fraction was $23 \pm 8\%$ and the peak troponin I was 896 ± 865 $\mu\text{g/l}$ (normal $< 1 \mu\text{g/l}$). The treatment modalities for all patients are summarized in table 1.

Coronary angiography was carried out in all cases within a mean delay of 5.8 ± 7 hours from symptom onset. Four patients had triple vessel disease, 3 had double and the three remaining single vessel disease. The culprit arteries were: the left main stem in one case, the left anterior descending in 5 cases, the circumflex in 2 cases and the right coronary in 2 cases. Angioplasty with stenting was successful in 80% of the patients (1.7 stents per patient). In the remaining 20% of cases no endovascular intervention was possible. Percutaneous revascularization was not complete in 3 patients. An intra-aortic balloon pump was placed in seven patients.

Tableau 1 Patient treatment characteristics (n = 10)

Admitted from:	
Ambulance service	8
Secondary transfer	1
Emergency department	1
Treatment onset	
Pain / ambulance service (hour)	3.9 ± 8
Pain / Coronary angiography (hour)	5.8 ± 7
Hemodynamic state	
Initial cardiac arrest	4
MI location: — Anterior	8
— Inferior	2
Initial state of shock	8
Intubation / ventilation	5
Inotropes : — adrenaline / dobutamine	8
— noradrenaline / dopamine	2
IABP	7
SAP (mmHg)	85 ± 13
Mean arterial pressure (mmHg)	64 ± 10
Transthoracic echocardiography :	
— mechanical complication	0
— ejection fraction (%)	23 ± 8

Mechanical circulatory assist device was implanted within a mean of 57 ± 92 hours following the diagnosis of cardiogenic shock. Five patients had MCS on the day of their admission, three others within 48 h of admission and two after a delay of more than a week. Extracorporeal membrane oxygenation was used in 8 cases while the two other patients benefited from more sophisticated ventricular assist devices: a Thoratec™ and a HeartMate II™.

Six patients died within a mean of 2.6 ± 1.3 days after ECMO assistance was initiated: three from multi-organ failure, two from irreversible neurological damage and one from fatal hemodynamic imbalance. Of the four surviving patients, one is still dependant on the implanted Heartmate II™ after 16 months and three have undergone heart transplant. Amongst these, two have benefited from the strategy of "bridge to transplantation" with one of them having a transplant 8 days after ECMO and the other after 200 days of assisted circulation with the Thoratec™ PVAD. The strategy "bridge to bridge" was used for one patient who was assisted by ECMO for 14 days before it was replaced by the Thoratec™ IVAD, with transplantation 72 days later. The mean time before a mechanical circulatory device was implanted was less than 24 h in the group of patients who died and 5.2 ± 5 days in those who survived (Table 2).

Discussion

The first report of mechanical ventricular assistance dates from 1966 (6). Since then surgical techniques, devices and methods of resuscitation have continuously improved. A recent meta-analysis (5), which grouped more than 500 patients with MCS for cardiogenic shock found a hospital survival rate in the order of 50%, comparable with that found in our study.

Tableau 2 Mechanical assistance and clinical outcome (n =10)

Mean time until implantation from onset of shock (hours)	57 ± 92
Type of device :	
ECMO	8
HeartMate	1
Thoratec	2 *
Outcome	
Survivors :	4
— Transplantation	3
— Definitive Assistance	1
Deaths :	6
Cause : — Systemic organ failure	3
— Neurological	2
— Hemodynamic failure	1
Mean time to death after MCS (days)	2.6 ±1.3

* 1 patient with ECMO followed by Thoratec

The utility of MCS in acute heart failure (7), hypothermia (8) and cases of acute drug intoxication is unquestioned due to its high success rate. The situation is very different in myocardial infarction. The studies published on the use of mechanical circulatory support in MI are difficult to interpret, due to their limited number (fewer than 30) and small sample size (1 to 26 patients). Other limitations of these studies include: the absence of randomization between conventional treatment approaches and MCS, the absence of comparable clinical criteria leading to the use of an assist device and the wide variation in the type of MCS device used.

Despite the absence of randomized trials or guidelines (9), it is clear now that patients remaining in cardiogenic shock despite conventional treatment (IABP, inotropes and revascularization) have no hope of survival. Under these circumstances the option of mechanical circulatory support should be considered particularly in those patients suitable for heart transplant.

The criteria leading to the use of an assist device post-MI remain to be defined. In our study only clinical data (arterial pressure, signs of peripheral shock, age and co-morbidities) were considered. Other studies have used hemodynamic parameters (10) and one even a prognostic score (11).

The timing of the implantation of the device would seem to be of the outmost importance. It must be carried out before multi-system failure becomes irreversible, even if evaluation of neurological function is often difficult to assess. As shown by Jaski et al. (12) in a group of 10 patients assisted after cardiac arrest, implantation of ECMO was achieved more quickly in those patients who survived (17±10 min) than those who did not (54±11 min). We found the opposite in the present study, all our patients who died had been implanted within 24 hours of their admission whereas the mean time to implantation in the survivors was 48 h. This finding is perhaps explained by the seriousness of the clinical condition in the non-surviving patients who already had a very poor prognosis at the time of implant of the MCS device. In fact four patients had presented with cardiac arrest and three of these died from the effects of irreversible neurological damage. The three other deaths in

our group were early (two from systemic organ failure and 1 from hemodynamic instability). The earlier the intervention is performed the better the results from mechanical circulatory assistance. However, this rapidity also means that sometimes patients will be implanted in whom the effects of cardiogenic shock are already irreversible. Under these circumstances, the method “bridge to bridge” becomes of interest. The results of Aiba et al. (13) seem to confirm this observation. In his series, 64 patients with post-MI cardiogenic shock received MCS, either by intra-aortic balloon pump or extracorporeal membrane oxygenation. If the patients were in severe cardiogenic shock there was 100% mortality regardless of the method of mechanical assistance, whereas if they were in a state of moderate cardiogenic shock survival rates were 38% with ECMO assistance and 5% with IABP.

Implantation of the MCS device needs to be achieved as quickly as possible in the case of cardiac arrest, but it would seem that for cases of refractory cardiogenic shock the most important prognostic parameter is the severity of the initial shock.

Considering the MCS devices used, Chen et al. (14) and Parkes et al. (10) used the more sophisticated type of device, Heartmate™, with a very high level of transplantation (70%) in the patients studied. Even if this type of system gives good results, it is difficult to recommend its front-line use for several reasons. Firstly implantation requires the absence of multisystem or irreversible neurological failure, something which is difficult to judge in an emergency situation. Additionally the implantation is a lengthy and expensive procedure, costing approximately 85,000 €. The ECMO System is cheaper (2,000 to 6,000 €), easy and rapid to position. Above all it enables temporary stabilization of hemodynamic parameters long enough to both evaluate the neurological state and decide on the subsequent treatment options (15). Therefore two strategies can be considered: 1) immediate emergency transplantation (ECMO acting as a “bridge to transplantation”), or 2) a strategy of replacement with a more performant device so that the patient can be assisted for as long as possible before transplantation, known as “bridge to bridge”.

In our patient series only two patients were implanted with the more complex type of mechanical assist device. In one case this was because of occlusive peripheral arterial disease and in the other due to controlled hemodynamics with neurological competence.

Our current practise in refractory cardiogenic shock is therefore fairly standard. It consists of the use of ECMO in those patients who are potential transplant candidates and secondarily, as a function of their general and neurological state, the patient either undergoes cardiac transplant or continues to be supported by a ventricular assist device.

We would like to draw attention to the recent introduction of a range of miniaturized centrifugal pumps (Impella® Recover LP 2.5 and 5, Aachen, Germany) which are mounted on a catheter and can be inserted via the femoral route to the left ventricle (16). An output of between 2.5 and 5 l/min can be generated. These devices show superiority compared with intra-aortic balloon pumps in terms of increased cardiac output in a randomized trial ISAR-SHOCK (17). Nevertheless, the better hemodynamic results achieved with the Impella® were not able to alter prognosis in the small test group. Another device implanted percutaneously, the Tandem Heart® (Cardiac Assist Technologies, Inc) has been evaluated and simi-

larly compared with IABP in a randomized trial. Despite improved hemodynamic parameters outcome at 30 days was comparable between the two groups in a series of 42 patients (18).

Our study is limited by the small number of patients, their relative heterogeneity (4 patients presented with cardiac arrest associated with the state of shock) and also from being a single-center study. A randomized, multicenter trial is ongoing in France comparing extracorporeal membrane oxygenation alone with ECMO combined with intra-aortic balloon pump in the treatment of MI complicated by cardiogenic shock.

Conclusion

We have shown that in acute myocardial infarction complicated by refractory cardiogenic shock, mechanical circulatory assistance combined with optimal conventional treatment enabled the survival of 4 out of 10 patients. In such clinically severe conditions, the use of circulatory assistance should be proposed systematically and discussed on a case by case basis taking into consideration the delays in treatment, the severity of the shock and above all, the ultimate possibility of transplant for the patient.

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